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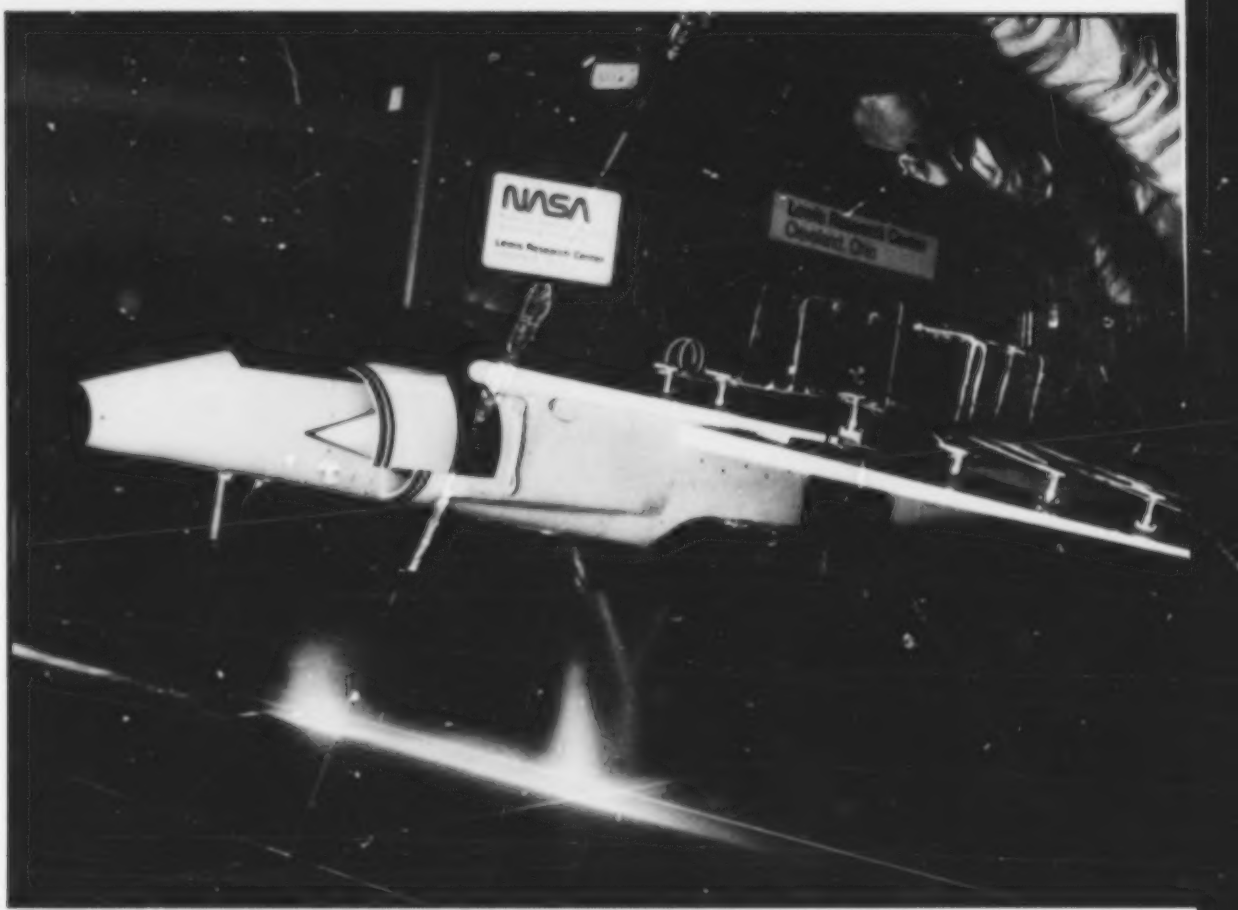

Lewis Research Center

R & D Facilities

NASA
National Aeronautics and
Space Administration

Lewis Research Center
Cleveland, Ohio 44135

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NAS 1.2:

Cover: *V/STOL aircraft model under test in the 8- by 6-Foot Supersonic Transonic and 9- by 15-Foot Subsonic Wind Tunnel.*

Lewis Research Center

R & D Facilities

NASA

National Aeronautics and
Space Administration

Lewis Research Center

Plum Brook Station

Foreword

The NASA Lewis Research Center defines and develops advanced technology for high priority national needs. The work of the Center is directed toward new propulsion, power, and communications technologies for application to aeronautics and space, so that U.S. leadership in these areas is ensured. The end product is knowledge, usually in a report, that is made fully available to potential users—the aircraft engine industry, the energy industry, the automotive industry, the space industry, and other NASA centers.

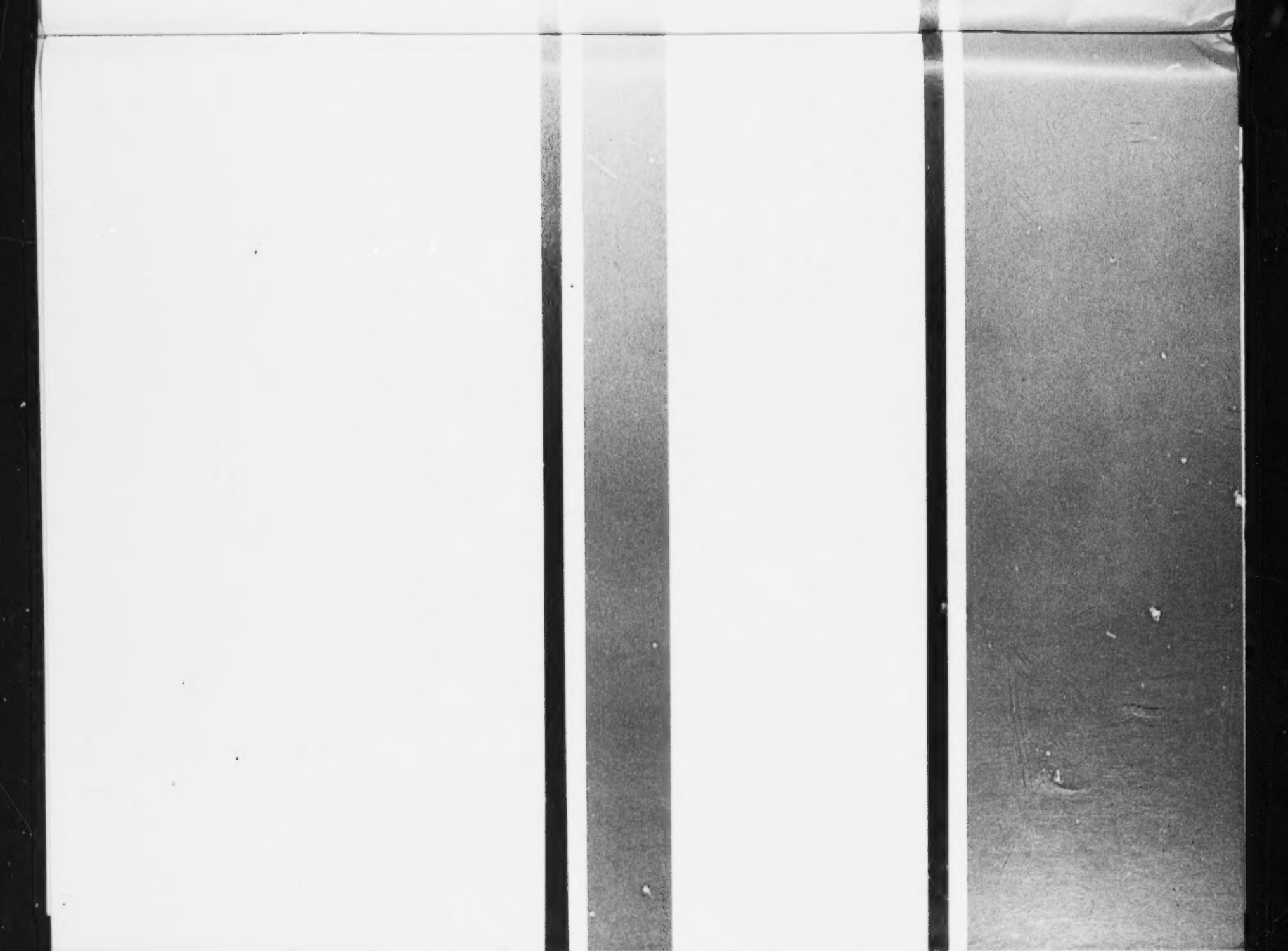
Lewis comprises over 150 buildings on a 350-acre main campus, adjacent to Cleveland Hopkins International Airport, and a 6400-acre Plum Brook field station near Sandusky, Ohio, 50 miles west of Cleveland. Since the groundbreaking at Cleveland on January 23, 1941, for the then Aircraft Engine Research Laboratory of the former National Advisory Committee for Aeronautics, more than $480 million has been invested in the Center's capital plant; estimated replacement cost is approximately $1.3 billion.

Over 5000 people staff Lewis, including civil service employees and support service contractors. Over half of them are scientists and engineers, who plan, conduct or oversee, and report on the research tasks and projects of the Center. They are assisted by technical specialists, skilled workers, and an administrative staff.

In addition to offices and laboratories for almost every kind of physical research in such fields as fluid mechanics, physics, materials, fuels, combustion, thermodynamics, lubrication, heat transfer, and electronics, Lewis has a variety of engineering test cells for experiments with components such as compressors, pumps, conductors, turbines, nozzles, and controls. A number of large facilities can simulate the operating environment for a complete system: altitude chambers for aircraft engines; large supersonic wind tunnels for advanced airframes and propulsion systems; space simulation chambers for electric rockets or spacecraft; and a 420-foot-deep zero-gravity facility for microgravity experiments. Some problems are amenable to detection and solution only in the complete system and at essentially full scale.

By combining basic research in pertinent disciplines and generic technologies with applied research on components and complete systems, Lewis has become one of the most productive centers in its field in the world.

This brochure describes a number of the facilities that provide Lewis with its exceptional capabilities.



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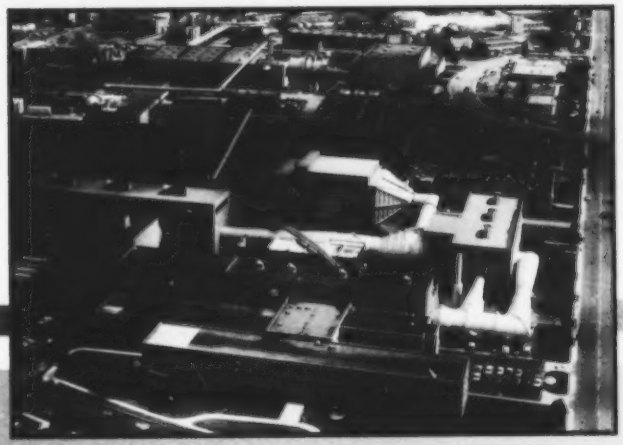
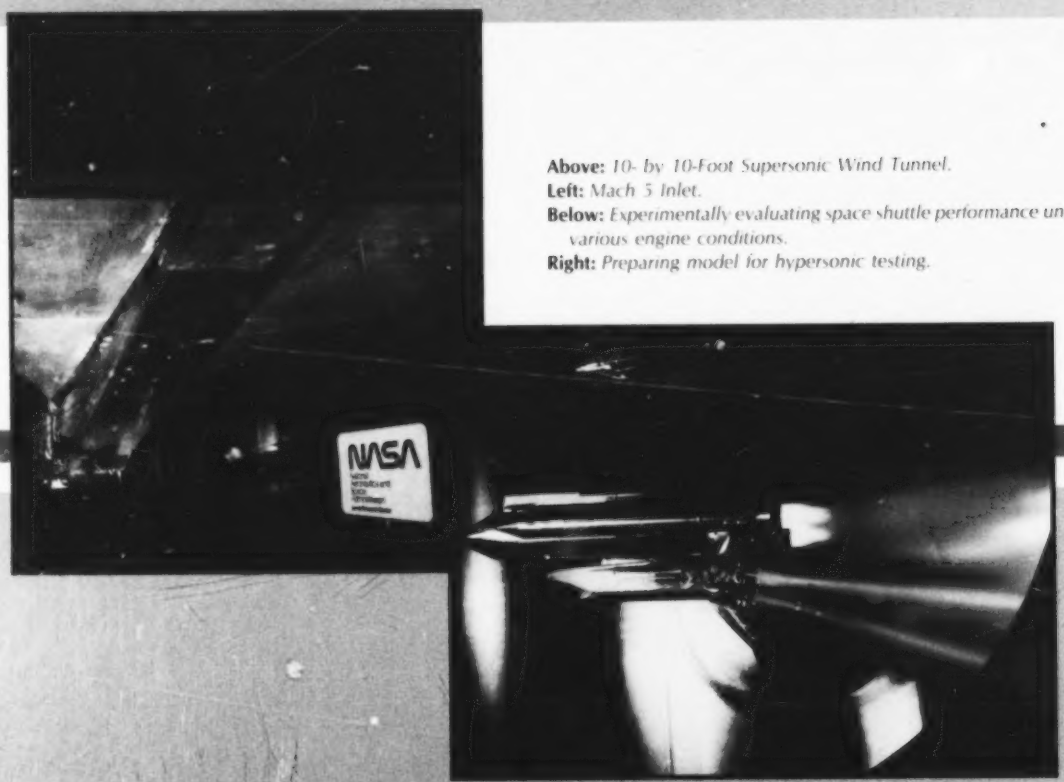
10- by 10-Foot Supersonic Wind Tunnel





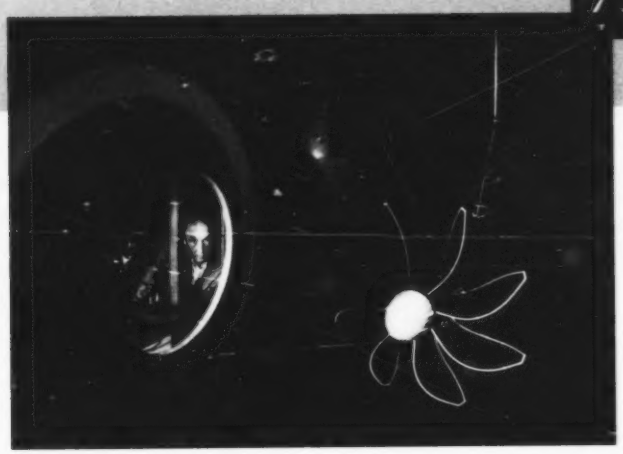
Above: *10- by 10-Foot Supersonic Wind Tunnel.*
Left: *Mach 5 Inlet.*
Below: *Experimentally evaluating space shuttle performance under various engine conditions.*
Right: *Preparing model for hypersonic testing.*

The 10- by 10-Foot Supersonic Wind Tunnel (SWT) has a flow range of Mach 2.0 to 3.5. The facility consists of an aerodynamic test section, main and secondary air compressors totaling 250 000 hp, closed-loop piping, an air-dryer building, an exhauster building, fuel storage, shops, an office building, and a water cooling tower. The tunnel is basically a propulsion tunnel that can also be operated as an aerodynamic (return type) tunnel for nonburning tests. The tunnel's large size permits full-scale testing of complete propulsion systems such as turbofan/turboprop aircraft engines and rocket motors.

The 10- by 10-ft SWT, which features a test area that is 10 ft high by 10 ft wide by 40 ft long, is capable of testing propulsion system performance at supersonic speeds. Altitude simulations of 50 000 to 150 000 ft are feasible in the aerodynamic mode. Stagnation pressures range from 200 to 5000 lb/ft^2, depending on Mach number and type of cycle. Stagnation temperatures range from 100 to 300 °F, although a maximum stagnation temperature of 600 °F can be attained for short periods in a propulsion cycle. Compressors 1 and 2 deliver air flow rates of 4.635 million ft^3/min and 1.350 million ft^3/min, respectively. Typical run durations are 1 to 2 hr in the summer and up to 8 hr in the winter. Major support systems include state-of-the-art data acquisition equipment with direct link to mainframe computers in the Research Analysis Center; various liquid and gas fuel systems; and altitude-exhaust, service, and combustion air.

Since its construction in 1955, the 10- by 10-ft SWT has supported a wide variety of aeronautical programs including investigations of space-shuttle-base heating, analyses of aircraft inlet stability, tests of advanced inlets and nozzles, and development of experimental liquid- and gaseous-fuel ramjets, to list just a few. Projected research includes performance testing of advanced propulsion system concepts, and off-design performance testing of hypersonic hardware.

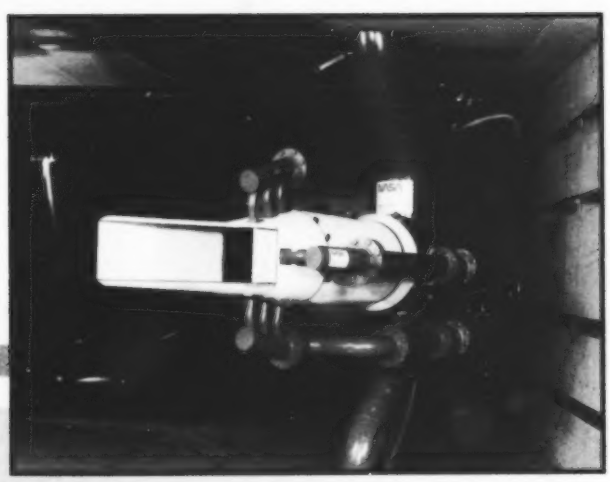
8- by 6-Foot Supersonic/Transonic and 9- by 15-Foot Subsonic Wind Tunnel



Above: *8- by 6-Foot Supersonic/Transonic and 9- by 15-Foot Subsonic Wind Tunnel.*
Left: *Single rotation propeller test in 8- by 6-ft SWT.*
Below: *Test of short landing maneuverability of an F16XL in the 9- by 15-ft SWT.*
Right: *Two-dimensional test of short diffuser inlet in 9- by 15-ft SWT.*

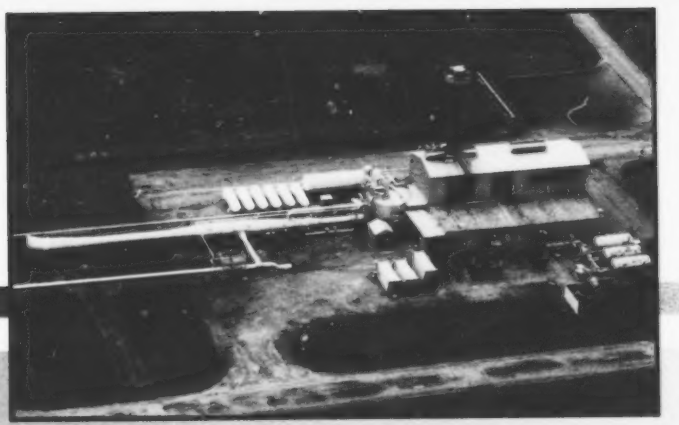
The 8- by 6-ft wind tunnel can be used as a closed-circuit tunnel for cold flow experiments and for testing aerodynamic models, or as an open-circuit tunnel for testing propulsion systems at Mach 0.4 to 2.0. A 9- by 15-ft test section housed in the return leg is used to test scale models of aerodynamic and propulsion systems and components for vertical/short take-off and landing (V/STOL) aircraft in wind velocities to 175 mph.

Tunnel air is driven by a seven-stage axial-flow compressor rated at 56 600 ft^3/min at a pressure ratio of 1.8. The compressor is powered by three induction motors with a total of 87 000 hp. The 8- by 6-ft test section is 8 ft high by 6 ft wide by 23 ft long. Top and bottom plates of the test section are removable for installation of model supports. The test section is perforated for transonic operation and provides variable porosity to about 6 percent. The 9- by 15-ft test section is 9 ft high by 15 ft wide by 28 ft long. It has been specially treated for acoustic testing of propulsion system components at frequencies down to 250 Hz. Unique capabilities of this test section include a high-angle-of-attack (up to 150°), 4-degree-of-freedom model support system with a high pressure/temperature air source, and vacuum for hot-gas reingestion testing. In addition, the 9- by 15-ft test section features laser Doppler velocimetry, and sheet laser for flow visualization. Both test sections feature high-speed viewing cameras and also a sophisticated data acquisition system that can be tied directly to powerful mainframe computers in the neighboring Research Analysis Center. This system provides on-line computation and display of test data.

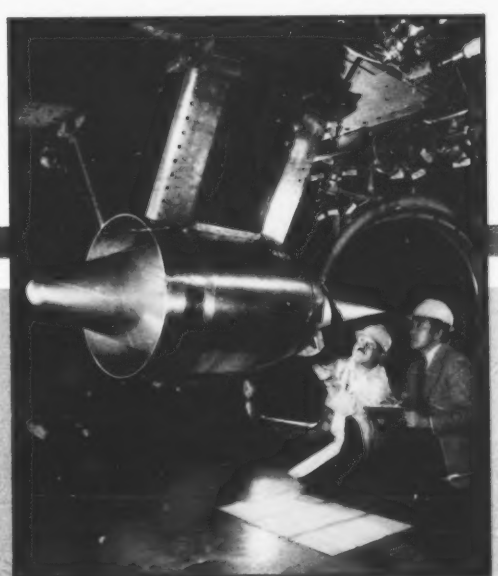


The work done in this facility comprises advanced turboprop research, V/STOL and unconventional inlet studies, baseline performance research, acoustic and noise suppression studies, hot-gas reingestion studies, and research that supports programs such as advanced turboprop development, the National Aerospace Plane, and the high-speed civil transport.

Hypersonic Tunnel



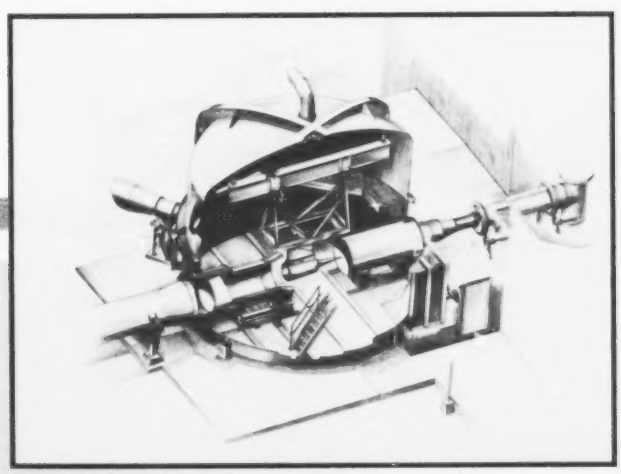
Above: *Hypersonic Tunnel Facility.*
Left: *Hypersonic engine setup for Mach 7 testing.*
Below: *Hypersonic research engine.*
Right: *Cutaway view of HTF test chamber with test article installed.*



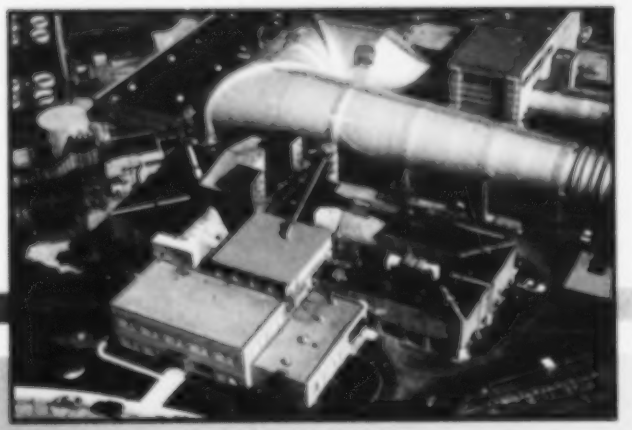
The Hypersonic Tunnel Facility (HTF) is a blowdown, freejet wind tunnel capable of simulating Mach 5 through Mach 7 flow velocities. The test chamber, which is fed through a 42-in. nozzle, allows articles up to about 2 ft in diameter by 10 ft in length to be tested. Temperature, altitude, and air composition can be generated for hypersonic engine or airframe structural tests in simulated flight environments. The high stagnation temperatures in this facility are produced by heating clean nitrogen gas with a 3.5-mW electric induction heater. The hot nitrogen gas is then mixed with clean oxygen to yield the air composition for the test.

Features of the facility include a 9-ft diameter by 40-ft tall electric induction heater capable of storing 77 million Btu at 5000 °R; storage for 700 000 ft^3 of gaseous nitrogen in addition to a smaller amount of gaseous oxygen; and onsite storage for liquid hydrogen (LH_2) in an 810-ft^3 Dewar supporting LH_2 flow rates of 5 to 45 lb/sec. Under normal operating conditions the facility can accommodate an approximate 5-min test run every 24 hours.

Currently, the HTF is the United States' only large *nonvitiated* hypersonic wind tunnel, producing high mass flow rates of high-temperature uncontaminated air. It is being reactivated to support generic hypersonic testing.



Icing Research Tunnel

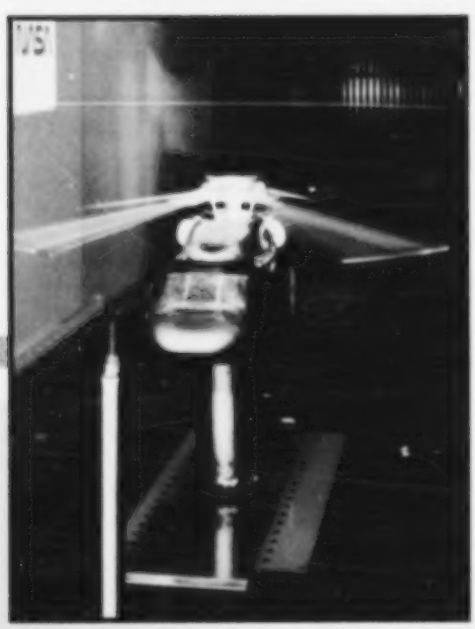


Above: *Icing Research Tunnel.*
Left: *Test model for evaluating properties of deicer fluid.*
Below: *Saab-340 engine nacelle icing test.*
Right: *Determining effects of icing on rotor performance.*

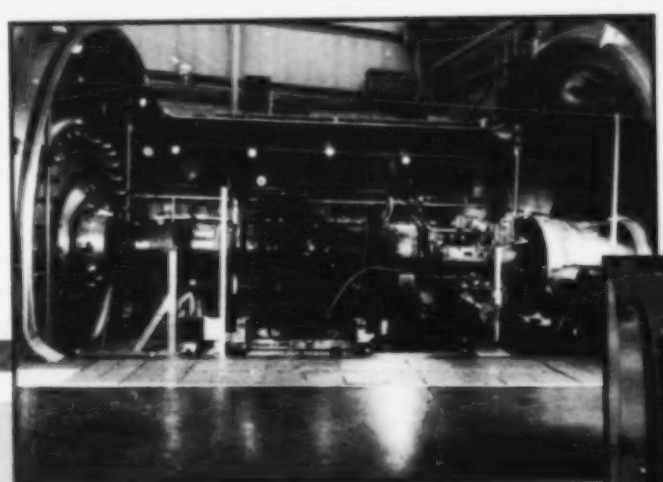
The Icing Research Tunnel (IRT) is the world's largest refrigerated icing tunnel. It is a closed-return atmospheric-type tunnel, whose major sections consist of a 5000-hp drive fan, a 2100-ton cooler, a water droplet spray bar, and a 300-mph test section. The tunnel is operated at atmospheric pressure and can simulate most natural icing conditions. It contains separate control rooms for the drive fan, spray bar, and test sections, and has a balance chamber, air-lock chamber, and shop and office areas.

The IRT can produce uniform icing conditions at speeds of 50 to 300 mph for a period of several hours. The test area measures 6 ft high by 9 ft wide by 20 ft long and is equipped with a turntable allowing test articles to be rotated $\pm 20^{\circ}$ from center. The total air temperature can be varied from about $+32$ to -25 °F and controlled within ± 1 °F. The water content of the air can be varied from about 0.2 to 2.5 g/m^3, and drop size can be independently varied from about 15 to 40 μm. Altitude exhaust rates of 3 to 80 lb/sec are computer controlled and are used to simulate flows for inlet models. Steam, heated air, service air, and electricity are also available. Instrumentation capabilities include over 200 channels of analog data for the test model and 92 channels reserved for facility parameters. The data acquisition system can be linked in real time to mainframe computers in the Research Analysis Center for timely reduction and analysis of experimental data.

Since its construction in the early 1940's, the IRT has played a vital role in the development of ice protection technology. Among other techniques, the hot-air anti-icing technology used on today's commercial transports was largely developed here. Advanced aircraft configurations and the high fuel cost associated with jet engine hot-bleed air for contemporary anti-icing techniques have created a strong demand for new deicing techniques; thus, the IRT is heavily used for developing new ice protection concepts. Some of the recent technologies being developed and evaluated are electromagnetic impulse deicing and electrothermal deicing.



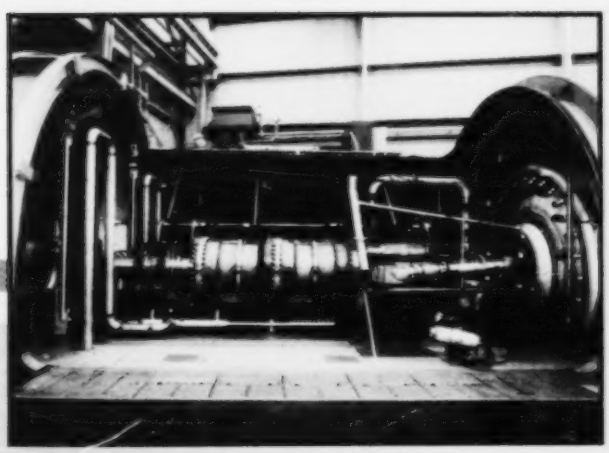
Propulsion Systems Laboratory



Above: *Propulsion Systems Laboratory.*
Left: *Facility for evaluating performance of carbon/carbon-lined nozzles with antioxidation coatings.*
Below: *Cold flow duct rig used to develop and calibrate facility controls.*
Right: *Hypersonic direct-connect rig capable of simulating Mach 6 flight conditions and/or flows.*

The Propulsion Systems Laboratory (PSL) is a altitude simulation facility capable of testing full-scale gas turbine engines operating continuously at simulated altitudes up to 70 000 ft and simulated velocities up to Mach 3.0. The PSL support complex consists of central air services equipment, an exhaust-gas cooler, a close-coupled air temperature conditioning plant, and a cooling tower water system. After components are tested in other facilities, complete engines are tested in the PSL, thereby enabling evaluation of complete systems and system interactions. Tests evaluate engine calibration, emissions, blade flutter, combustion stability, engine/nozzle controls, inlet flow distortion, engine stability, nozzle systems, heat transfer, advanced materials, performance, and transient characteristics.

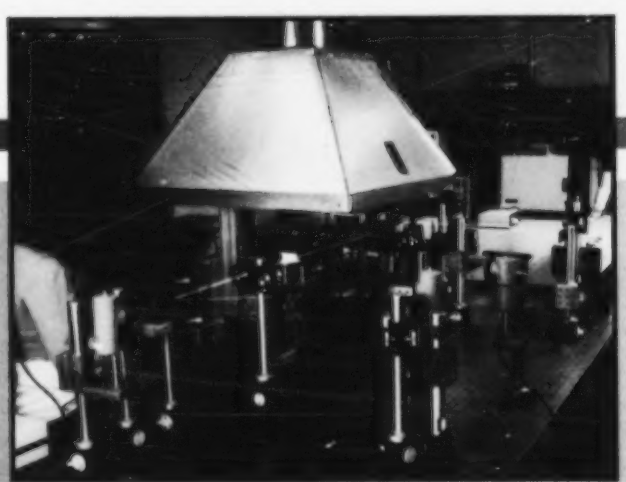
The PSL consists of two engine test cells, each of which are 24 ft in diameter and 38 ft in length. Engines are mounted on frames that can measure up to 100 000 lb of thrust; their inlets are connected directly to the facility inlet-air supply and then are sealed within the test cells. Flight simulation is accomplished by closely controlling the test chamber altitude as well as the inlet-air pressure and temperature, so as to match conditions that the engine would be exposed to in actual flight. Air is supplied to the engines at flow rates up to 480 lb/sec and at pressures up to 165 psia; it can be temperature conditioned between −60 and +800 °F. New thrust measurement systems enable testing of deflected thrust exhaust systems that produce vertical and lateral thrust as well as axial thrust. A recent modification, to supply inlet air in limited quantities at temperatures up to 3000 °F, allows testing in the hypersonic regime (up to Mach 6.0).



Research programs conducted in the PSL have significantly advanced the technology of modern commercial and military power plants. Fuel efficiency has been increased while emissions and noise have been reduced. Safety has been enhanced by improved materials, engine stability, and control systems. Future research will include highly integrated controls studies, multifunction exhaust system evaluations, high Mach number turbomachinery development, and advanced material core engine development.

Engine Research Building

Above: *Engine Research Building.*
Left: *Mapping heat transfer coefficients of generic transition ducts to validate computer prediction.*
Below: *Studying flame characteristics by intrared radiometry.*
Right: *Large, low-speed centrifugal compressor acquires detailed flow field measurements to assess emerging CFD codes.*



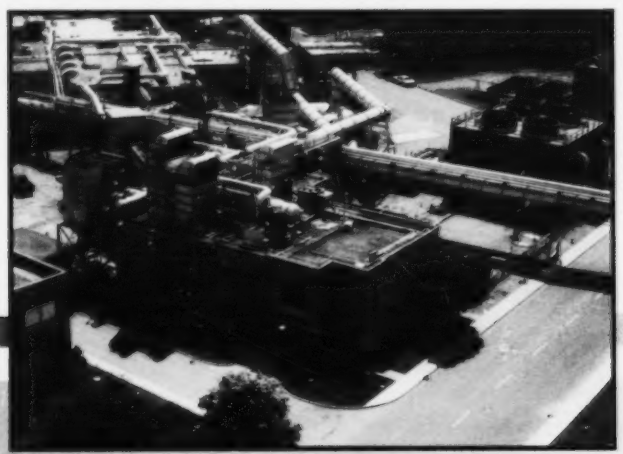
The Engine Research Building (ERB) is the largest single-facility test complex at Lewis Research Center. The complex houses over 65 test cells in addition to office space, laboratories, photographic and printing facilities, shop areas, and a cafeteria. It also houses portions of the Centerwide air-supply and altitude-exhaust systems. Among the broad categories of work performed in the facility are experimental engine-component research (compressors, turbines, and combustors), nozzle and transition duct studies, development and testing of advanced instrumentation and controls, and acoustic/wave phenomenon experiments. Although ERB facilities are used primarily for experiments in aeronautical research, materials development studies and space power experiments are also conducted here.

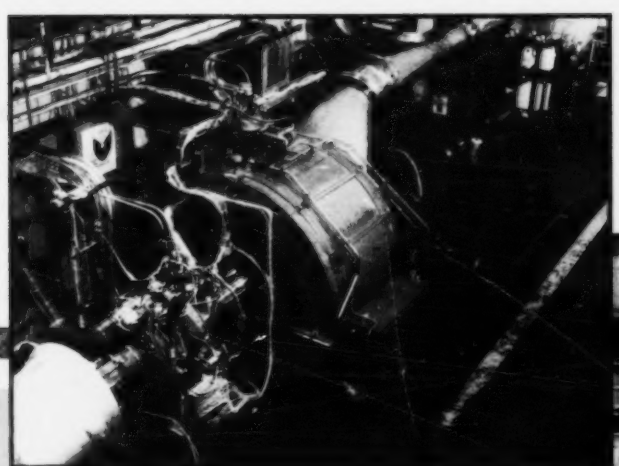
The ERB can simultaneously support a wide variety of research. Utilities within the complex include dry, pressurized air, high-pressure heated air (1200 °F), refrigerated air (– 70 °F), altitude exhaust, and steam, as well as various fuel-delivery systems. State-of-the-art instruments include infrared imaging, schlieren, and specialized laser systems such as laser Doppler velocimetry. Besides stand-alone data systems, high-speed systems linked to mainframe computers in the Research Analysis Center permit extremely fast acquisition and reduction of data from complex experiments.

Since the early 1940's, the ERB has supported a wide variety of basic and applied research and development. Major advances in turbojet propulsion, high-performance compressor and turbine systems, cryogenic propulsion systems, noise abatement systems, high-speed combustor systems, and supersonic throughflow technology are just a few results of the activities conducted here.

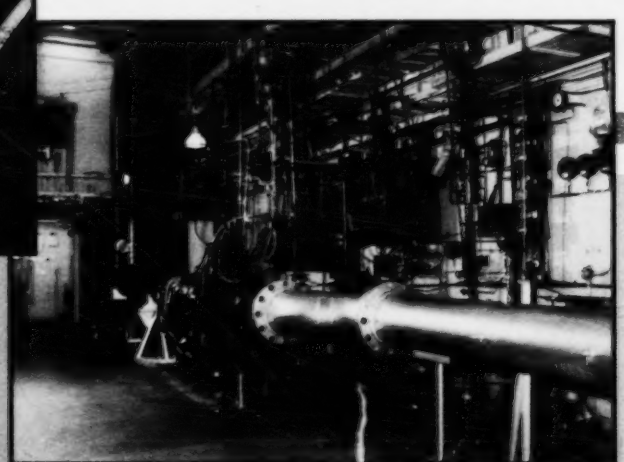
Aeronautical Research

Engine Components Research Laboratory





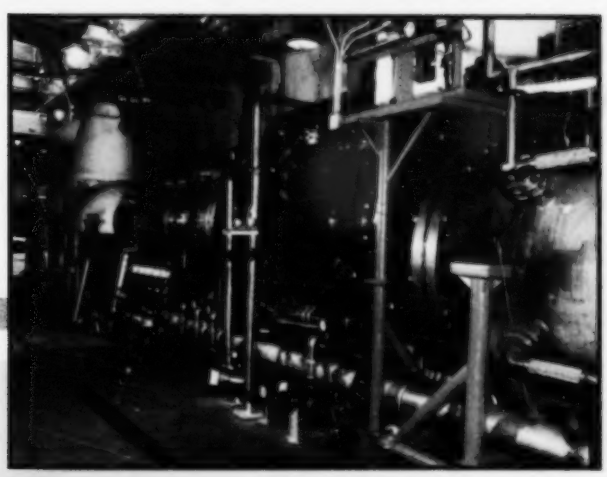
Above: *Engine Components Research Laboratory.*
Left: *Small turboshaft engine rig.*
Below: *Heat transfer tunnel.*
Right: *Full-scale combustor rig.*



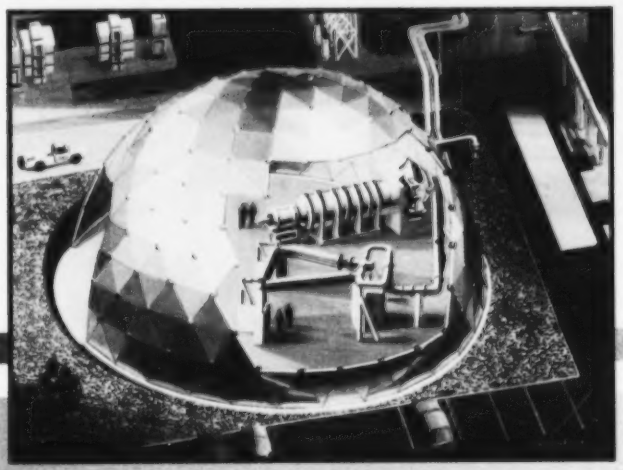
The Engine Components Research Laboratory (ECRL) consists of three separate test rigs designated 1A, 2A, and 2B. Test rig ECRL 1A is a full-scale combustor/augmentor rig connected directly to the central air and altitude-exhaust systems. This rig supplies jet aircraft fuel to experimental combustors and provides inlet-air flows up to 100 lb/sec. A gas analyzer provides on-line analysis of the exhaust gases produced. The testing done on this rig aids in the development of high efficiency engines.

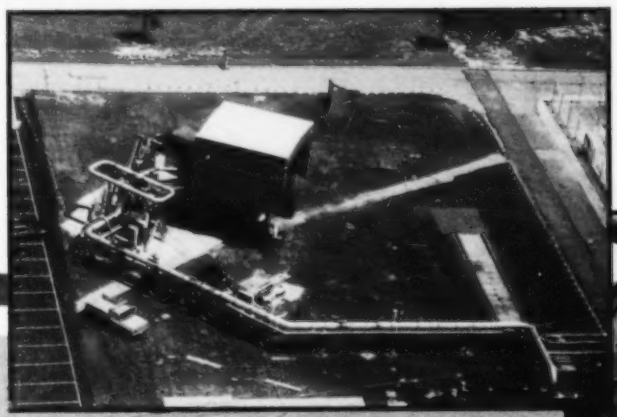
Test rig ECRL 2A is a small-components rig that can simulate combustor exhaust temperatures. The rig, which is connected directly to the central air system, uses natural gas and jet aircraft fuel to heat the air. Turbine nozzles, blades, and other hot components are tested at the simulated combustor outlet conditions predicted for more advanced engines.

Test rig ECRL 2B is a full-scale, sea-level test stand for shaft output gas turbine engines. The stand is equipped with a 2500-hp programmable power absorber that can simulate rotor-system inertia. Engine performance, inlet temperature and pressure distortion, and shaft vibration have been investigated on this test stand.

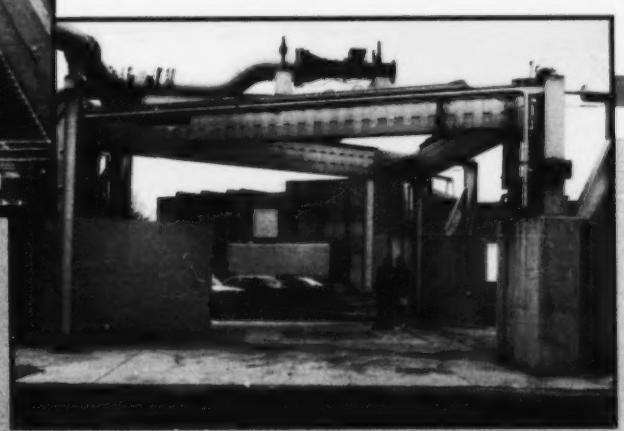


Powered Lift Facility





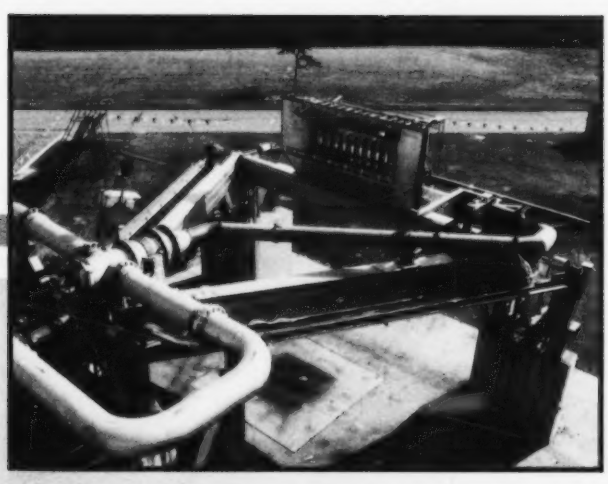
Above: *Powered Lift Facility.*
Left: *Ejector-augmented lift hardware on the powered lift thrust frame.*
Below: *PLF prior to construction of acoustic barrier dome.*
Right: *Rig configured for nozzle acoustic testing.*



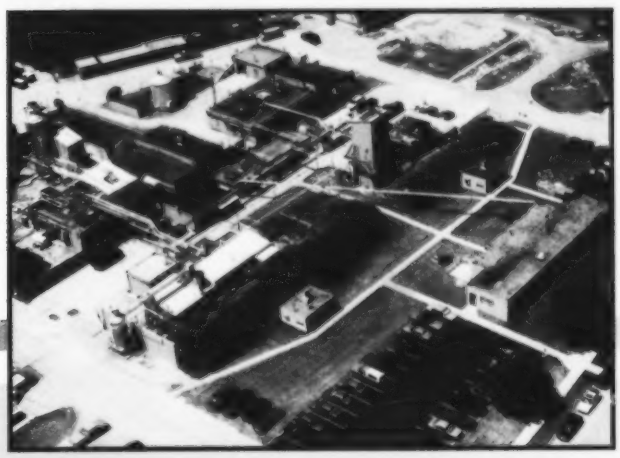
The Powered Lift Facility (PLF) permits testing of full-scale propulsion lift concepts such as ventral nozzles, ejectors, and afterburner-augmented lift systems. The facility is equipped with a 3-axis, 6-degree-of-freedom thrust balance. The balance is a 30-ft equilateral triangle whose top surface is 15 ft above the ground; it is calibrated by applying measured hydraulic loads at seven different locations on the balance. The facility, which is connected directly to the central air system, allows engines or large burners to be operated on the test stand.

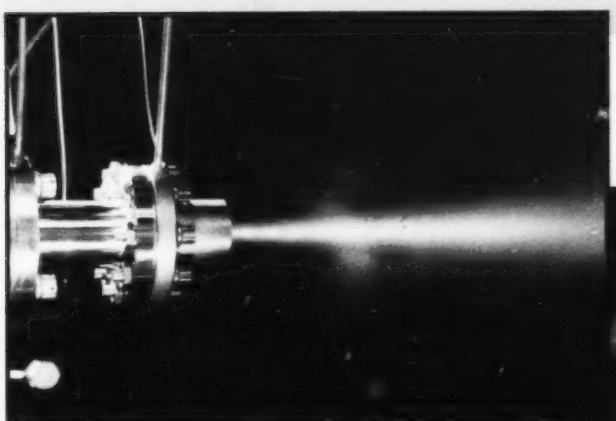
This facility can provide fuel flow of 30 gal/min at 1000 psig, and combustion air flow of 150 lb/sec at 125 psig. It can accommodate hardware weighing as much as 35 000 lb and is rated at 60 000 lb of vertical thrust, 25 000 lb of axial thrust, and 10 000 lb of lateral thrust. The nozzle acoustic test rig (NATR) is located adjacent to the PLF. This new test rig is designed to study the propulsive performance and acoustic characteristics of high-speed research nozzles. Services available to this rig are 450- and 125-psig combustion air, a two-trailer gaseous hydrogen (GH_2) system, and GH_2. A state-of-the-art acoustic data system is also available.

The PLF, a relatively new test facility at Lewis, is used for computational fluid dynamics studies as well as for studies on the performance of full-scale systems over a wide range of pressures and temperatures. The PLF and NATR are located inside a newly built, dome-shaped acoustic enclosure. This enclosure is designed to keep test noise from disturbing the surrounding communities and to allow accurate acoustic measurements for research programs.



Rocket Laboratory





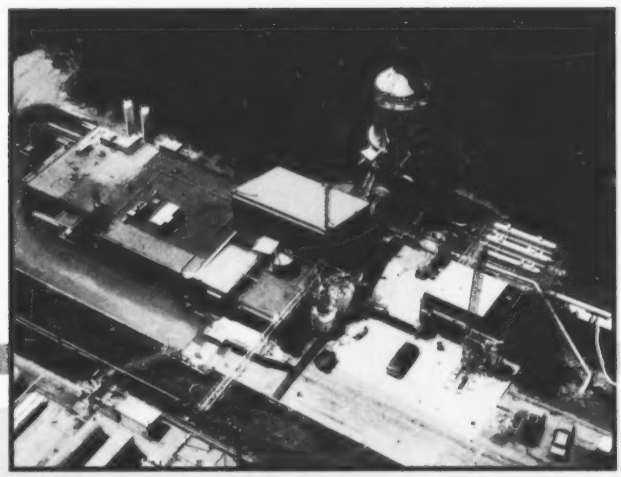
Above: *Rocket Laboratory.*
Left: *Low-thrust methane-oxygen rocket engine test.*
Below: *Engineers study the heat transfer properties of cryogenic droplets.*
Right: *Metallized-propellant rocket engine test stand.*

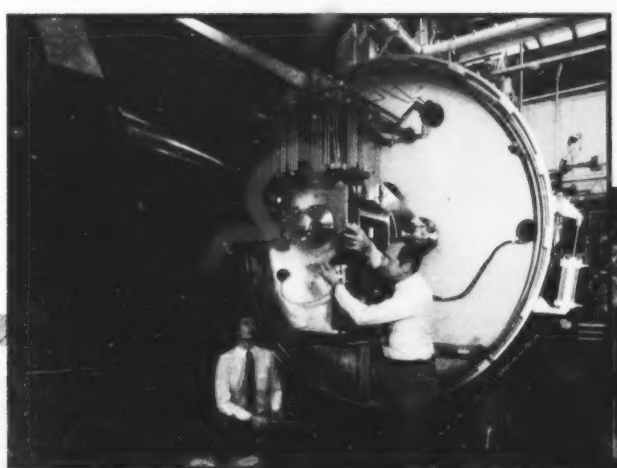
The Rocket Laboratory is a complex of nine independent and unique test facilities that support research in diverse areas of space power and space propulsion. Facilities are available to test rocket engine components and materials at thrust levels ranging from 5 to 1000 lbf, at sea level and at altitude pressure conditions, with a variety of chemical propellants. In a separate test rig, a hydrocarbon/air burner is used to investigate fuel-rich combustion processes. Also, hydrocarbon-lubricated bearings can be tested at speeds up to 25 000 rpm. Several of the facilities are engineered as cold-flow test rigs wherein flows and sprays of fluids such as liquid nitrogen, metallized propellant, and two-phase solid-gas aerosols are analyzed. There is an optical laboratory to develop optical measurement technologies.

The Rocket Laboratory can support all aspects of chemical combustion, rocket engine components testing, and fluid flow systems development. Test articles can be provided with reactants such as gaseous hydrogen, oxygen, and carbon monoxide, hydrocarbons, and metallized propellants, as well as more general services such as gaseous nitrogen and helium, compressed air, and domestic water. Although each of the separate facilities has unique features, all of them have advanced data acquisition and control techniques that enable them to quickly and easily adapt for changes in research programs or program requirements. Such flexibility promotes high productivity and high facility utilization.

The laboratory has recently witnessed the first successful combustion of carbon monoxide and oxygen in a rocket engine—one step toward developing this propellant combination for Mars missions. Also, prototype turbine blades fabricated from ceramic matrix composites were successfully tested in severe heat flux environments, thereby demonstrating their ability to withstand the thermal loads of the space shuttle main engine turbopumps. One of the future objectives for this laboratory is the construction of a completely new rocket engine test cell in which the capabilities of existing rocket engine test stands will be combined with a laser-based diagnostics laboratory in which a variety of nonintrusive measurements can be taken.

Rocket Engine Test Facility



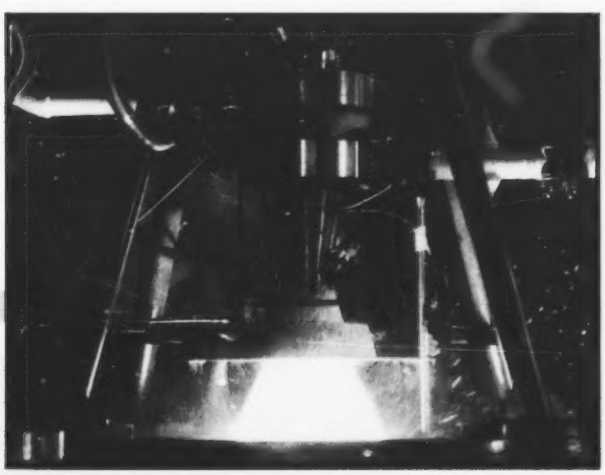


Above: *Rocket Engine Test Facility.*
Left: *Altitude engine test stand.*
Below: *Turbomachinery test stand.*
Right: *Engine test on sea-level test stand.*

The Rocket Engine Test Facility (RETF) consists of three discrete test stands. Two stands are configured for firing pressure-fed engines, and the third, for testing cryogenic turbopumps. A remotely located control and operations center ensures maximum test firing safety.

The RETF includes a vertically mounted test stand, with a 50 000-lb thrust capacity, suitable for test-firing engines at sea-level conditions; a horizontally mounted engine test stand, with a 5000-lb thrust capacity, capable of firing engines at 100 000-ft altitude pressure conditions; and a turbopump stand configured for testing liquid-hydrogen and liquid-oxygen turbopumps. Hydrogen/oxygen-propellant engines can be test-fired at chamber pressures in excess of 2000 psi.

This facility enabled extensive pioneering research and development in rocket science. Here, breakthrough advances occurred in engine fabrication techniques, combustion stability, high engine-chamber pressures, high-mixing-efficiency injectors, and chamber-wall cooling schemes. The sea-level stand is being modified to test fully integrated engines (propellants fed from on-board turbopumps) for the space engine program. The turbopump stand will soon be able to provide hot-gas generation for powering drive turbines of turbopump packages.



Space Power Research Laboratory

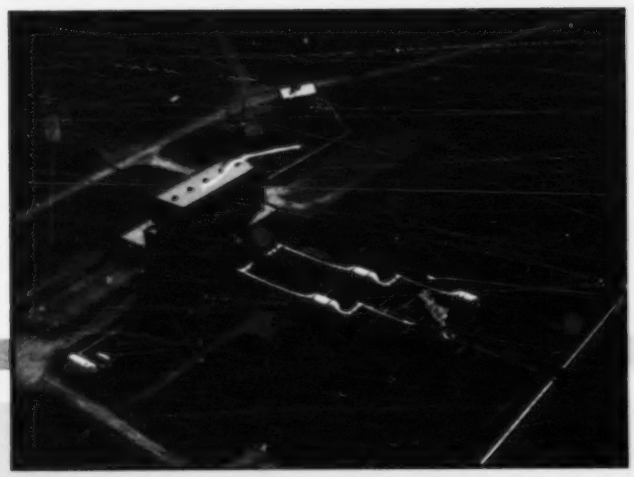
Above: *Space Power Research Laboratory.*
Left: *Testing lightweight Ni-H_2 battery.*
Below: *Measuring impedance of Space Station Freedom Ni-H_2 cells.*
Right: *Electrochemical testing of fuel cell catalysts.*

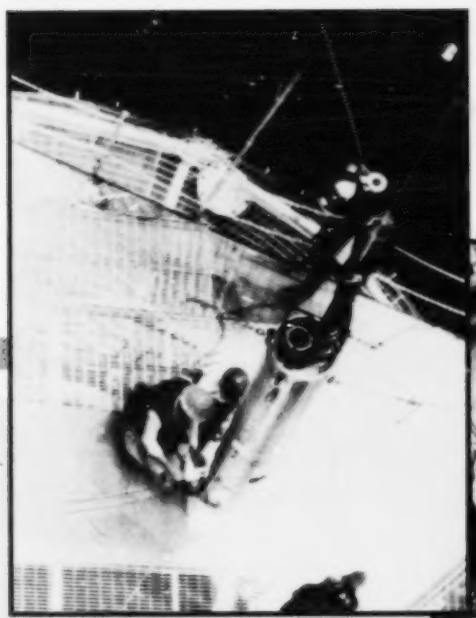
In the Space Power Research Laboratory, research and development of advanced electrochemical power systems is conducted for future NASA missions. Recent efforts have centered on developing lightweight nickel-hydrogen batteries and advanced hydrogen-oxygen fuel cells.

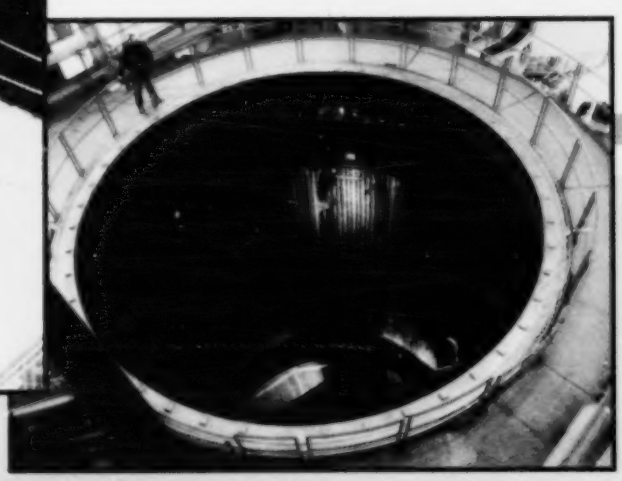
The laboratory can support all phases of battery cell development, from inception through load testing of flight capable prototypes. It is equipped with apparatus for developing and evaluating new battery components and for developing advanced fuel-cell catalysts, and it has computerized hardware capable of complete life-cycle testing of prototypes under space loading conditions.

In this laboratory, numerous advances were made in electrochemical power systems, and the extremely successful nickel-hydrogen battery cells powering the Hubble Space Telescope were developed. The facility currently supports basic research and development of battery cells for the Space Station Freedom Program.

Spacecraft Propulsion Research Facility





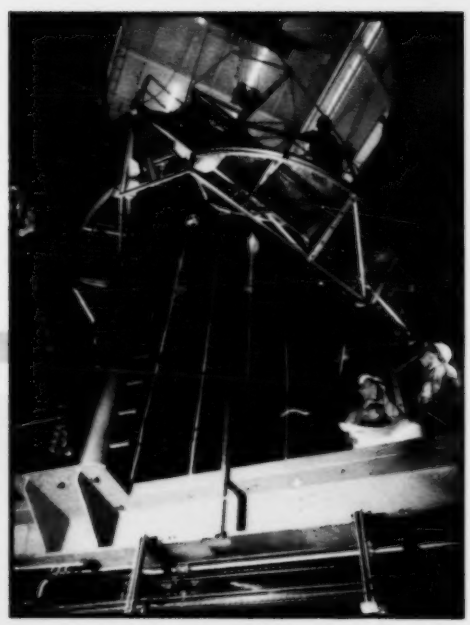


Above: *Spacecraft Propulsion Research Facility.*
Left: *SPEAR I flight hardware setup for test.*
Below: *Main test chamber.*
Right: *Centaur rocket mounted in test chamber.*

The Spacecraft Propulsion Research Facility is the largest space-environment test chamber in the United States for full-scale rocket engine testing at up to 100 000-lb thrust. Designed to test liquid-hydrogen/oxygen rocket engines, it houses a 38-ft-diameter by 55-ft-high stainless steel test chamber. A separate control and data building is located a safe distance from the main test facility.

The facility can provide sustained high vacuum (10^{-6} torr); solar thermal simulation via a quartz lamp array; a 250-ton floor load capacity; a liquid-hydrogen (LH_2) supply to the test articles via vacuum-jacketed piping and installed chamber penetrations; a 200 000-gal low-leakage LH_2 storage Dewar nearby; additional LH_2 storage in railcar-mounted Dewars; a 19 000-gal propellant safety dump tank and a 6000-gal liquid oxygen (LO_2) oxidizer safety dump tank located below the test chamber, to receive and contain accidental LH_2 or LO_2 spills; and a water spray chamber/steam ejector system to cool/remove rocket exhaust.

Since this facility previously supported Centaur rocket tests, there is proven experience handling 6000-gal tanks of LH_2 and 3000-gal tanks of LO_2 within the test chamber. More recently, certification and baseline tests of unique flight hardware were done here. In the future, it is anticipated that the facility will be used for additional rocket engine testing and advanced aerospace engine development.

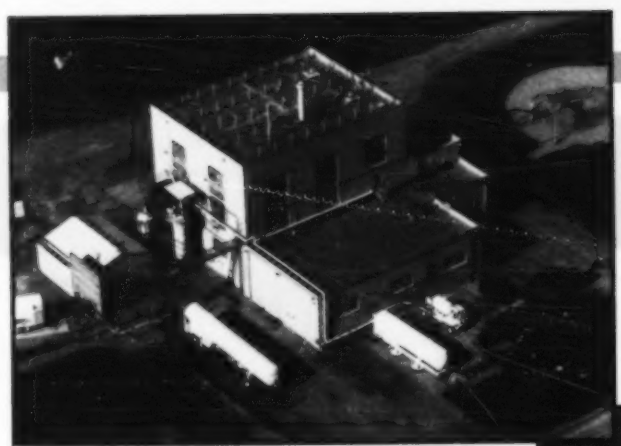


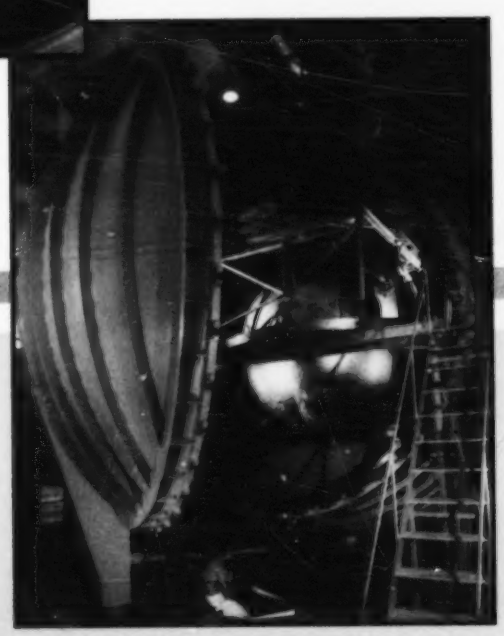
Cryogenic Propellant Tank Facility

The Cryogenic Propellant Tank Facility is a 25-ft-diameter space-environment test chamber with a 20-ft-diameter door. The facility's design and construction allow large-scale liquid hydrogen (LH_2) experiments to be conducted safely. Furthermore, to ensure maximum safety, control and data collection operations are located in a separate, remote building.

Some features of this facility are a removable LH_2/LN_2 cryogenic cold wall with vacuum-jacketed LH_2 piping and chamber penetrations, electrical control systems with explosion-proof hardware, a hydraulic shaker system, and a vacuum-jacketed LH_2 dump line and burn-off stack to handle accidental LH_2 spills inside the chamber. Currently, this facility can provide vacuum to 10^{-6} torr, or lower if the LH_2 cold wall is used.

The Cryogenic Propellant Tank Facility continues to play an essential role in the development of advanced insulation systems and on-orbit fluid transfer techniques for flight-weight cryogenic fuel tanks and insulation systems. Recently, experiments were conducted in the production and utilization of slush hydrogen (a space-efficient mixture of liquid and frozen hydrogen). The facility is equipped with an 800-gal slush hydrogen batch production plant. Results of such experiments will have application in the National Aerospace Plane and other advanced cryogenic-fuel engines.





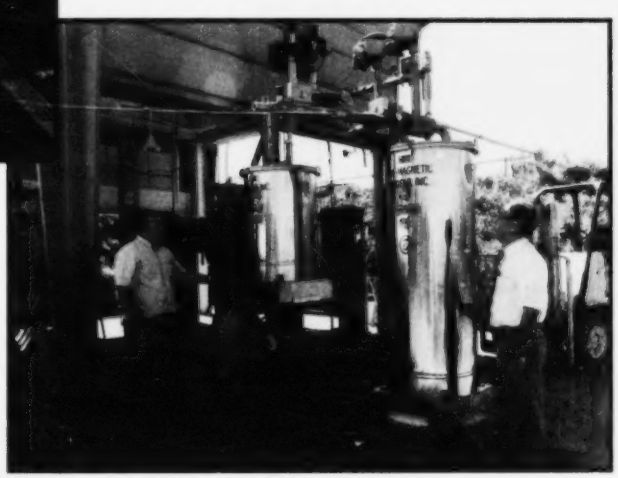
Left: *Cryogenic Propellant Tank Facility.*
Below: *Propellant tank system (large sphere) installed in chamber.*

Cryogenic Components Laboratory

The Cryogenic Components Laboratory (CCL) consists of six test cells housed separately in remote buildings surrounding a centrally located control building. The test cells are configured for research on either rotating or nonrotating component packages. Test articles are assembled in a clean room at the control building and then moved to the appropriate test cell. Support services available in the test cells are gaseous hydrogen, helium, and nitrogen, and liquid hydrogen, oxygen, and nitrogen. Rotating test articles are driven with cold-gas turbines.

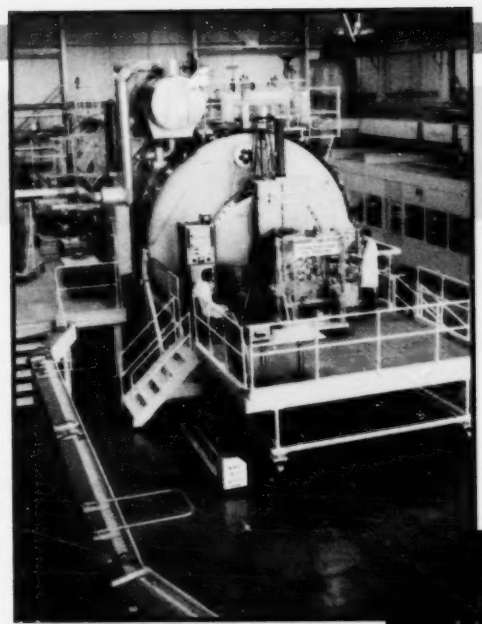
In the CCL complex, specimens can be tensile tested with pulls of up to 400 000 lb at temperatures ranging from 70 (ambient) down to −320 °F. Specimens can also be fatigue-tested to 30 Hz at temperatures as low as −460 °F. Pressure vessels can be low cycle tested at cryogenic temperatures. Test cells have explosion-proof electrical hardware and high ventilation rates to allow testing with hydrogen.

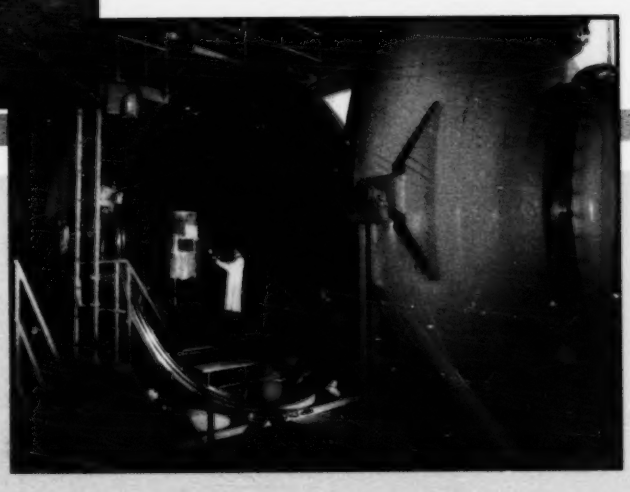
Since construction in 1961, the Cryogenic Components Laboratory has been used to characterize material properties at low temperatures and to evaluate the design performance of prototype components and systems. The complex now supports development of new materials and designs for use in cryogenic systems and the temperature extremes of space. In the future, water pump performance will be examined. A new closed-loop water tunnel, to be housed in one of six test cells, will be driven to rotative speeds in excess of 7000 rpm by a 500-hp variable-speed electric drive motor with a gearbox increaser.



Left: *Cryogenic Components Laboratory.*
Below: *Cryogenic liquid transfer test rig for LH_2 and LN_2 testing.*

Electric Power Laboratory



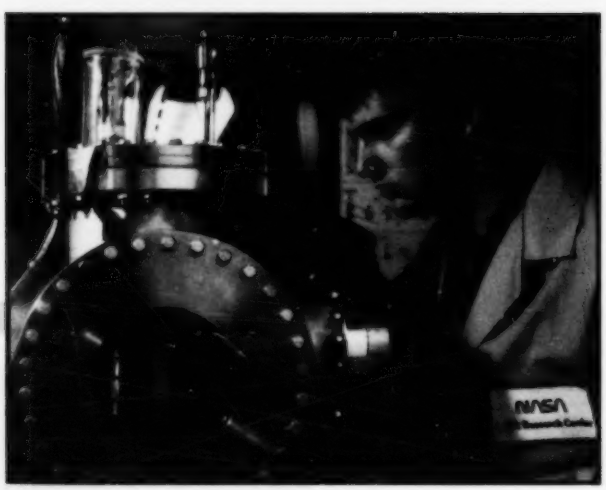


Above: *Electric Power Laboratory.*
Left: *Space-environment chamber with ion thruster installed in test port.*
Below: *Spacecraft-environment interaction test.*
Right: *Bell jar used in engine component development and testing.*

The Electric Power Laboratory (EPL) supports research and development of spacecraft power and electric propulsion systems. Activities are focused on four types of propulsion devices: resistojets, arcjets, ion engines, and magnetoplasma dynamic thrusters. The EPL features two very large space-environment simulation chambers; intermediate and smaller size chambers suitable for testing small engines or components; bell jars used for development and small-scale component testing; and support areas, including an electronics shop, machine shop, clean room, systems control room, and office space.

The EPL can support all phases of a propulsion or power system program, from inception through operational testing of flight-ready hardware. A major feature of the facility is its two large (15-ft-diam by 65-ft-long and 25-ft-diam by 70-ft-long) space-environment chambers, each capable of testing full-scale low-thrust engines. Both chambers are equipped with several air-locked access ports, support cranes, independent roughing and diffusion vacuum systems, and a cryogenic cold wall; these chambers can provide a vacuum of 10^{-6} torr. The larger chamber has radiation surfaces of -320 °F. The multiple air-locked access ports allow several tests to be conducted simultaneously in each chamber without cycling the chamber back to atmospheric pressure during introduction or removal of test hardware. Because of this feature, facility productivity, efficiency, and utilization are extremely high.

This laboratory has made significant contributions to the field of electric propulsion systems, including the development of small thrusters that use the spacecraft's spent fluids as a propellant. Currently, work is directed toward programs on electric propulsion and advanced power, environmental interaction studies on spacecraft surfaces and power systems, thermal vacuum tests of spacecraft and related components, and development programs for the Space Station Freedom.

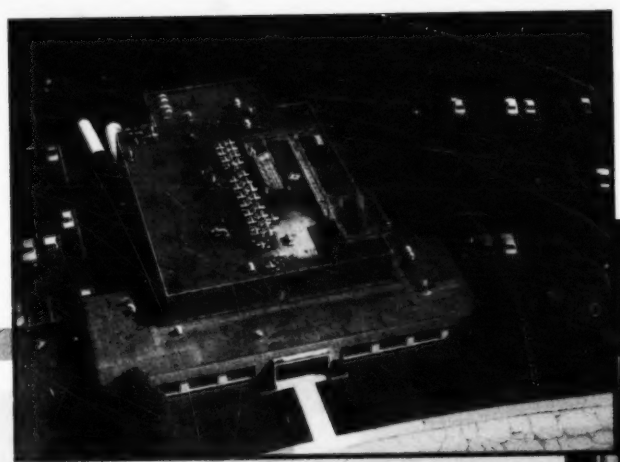


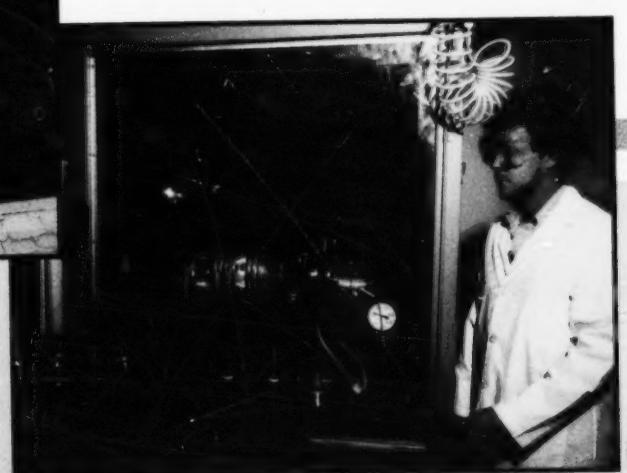
Energy Conversion Laboratory

The Energy Conversion Laboratory (ECL) houses laboratories dedicated to the development of new photovoltaic technologies for space applications. Research conducted in this facility supports high-altitude test flights on the Lewis Learjet that are a primary source of reliable data on space solar-cell performance.

The ECL supports virtually every process required to design, fabricate, and characterize space solar cells and solar-cell modules. Two organometallic chemical vapor deposition reactors deposit basic solar-cell semiconducting materials. A photolithographic system along with vacuum sputter, electron beam, and evaporative coating systems are used to pattern, contact, and add antireflection coatings to solar cells. Electrical properties are studied with a variety of techniques, such as computerized transport measurements, photoluminescence, deep-level transient spectroscopy, and electron-beam-induced current. Physiochemical characterization studies are done by scanning electron microscopy and secondary-ion mass spectrometry. Both radiation exposure and thermal cycling tests are conducted on solar cells to investigate the effects of these space-environment conditions.

The ECL has contributed fundamentally to the development and refinement of the existing photovoltaic power systems. Current and projected research is directed at developing a new generation of solar cells based on such materials as gallium arsenide and indium phosphide, which offer potential for greatly improved efficiency, lower weight, and longer lifetimes.





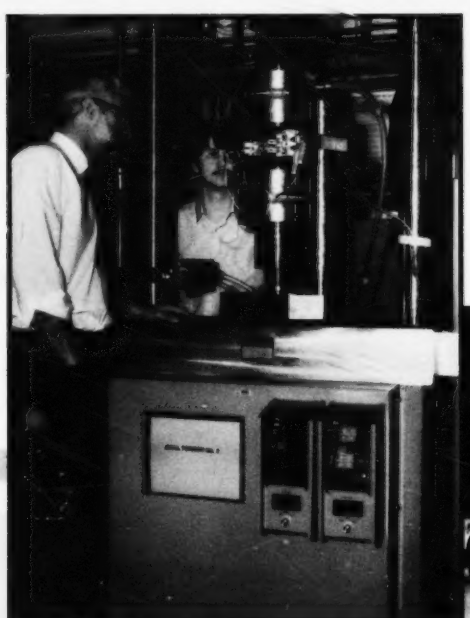
Left: *Energy Conversion Laboratory.*
Below: *Growing a gallium arsenide solar cell layer via an organometallic chemical vapor deposition process.*

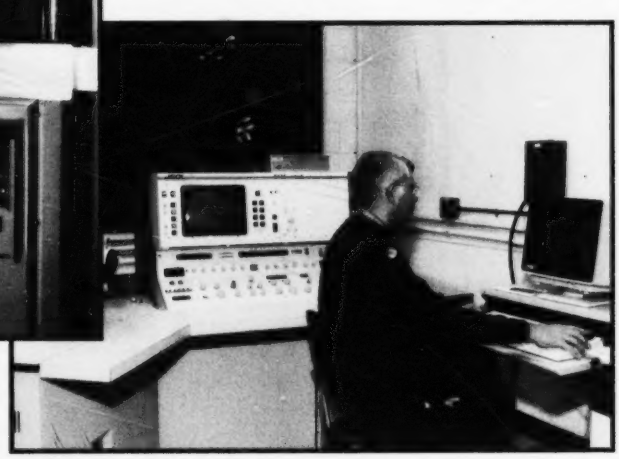
Materials and Structures Complex

The Materials and Structures (M&S) Complex is a group of laboratories housed in various buildings throughout the Center. In these, a wide variety of structural and materials research is conducted on compounds such as superalloys, powdered materials, polymers, composites, and ceramics. This research often involves investigating materials properties under extreme environmental conditions.

The M&S laboratories are equipped to conduct a broad range of materials and structural evaluations, such as tensile, creep rupture, and fatigue strength tests, under conditions varying from −420 (cryogenic) to +6000 °F. In addition to a considerable variety of strain and load-controlled fatigue testing equipment (including unique systems capable of fatiguing materials at 1100 Hz), the complex also contains high-velocity (to Mach 1) burner rigs for simulating thermal cycles of an operating engine. The complex includes a materials processing laboratory, a complete metallurgical/chemical analysis laboratory, and facilities dedicated entirely to structural integrity, dynamics, and mechanics research.

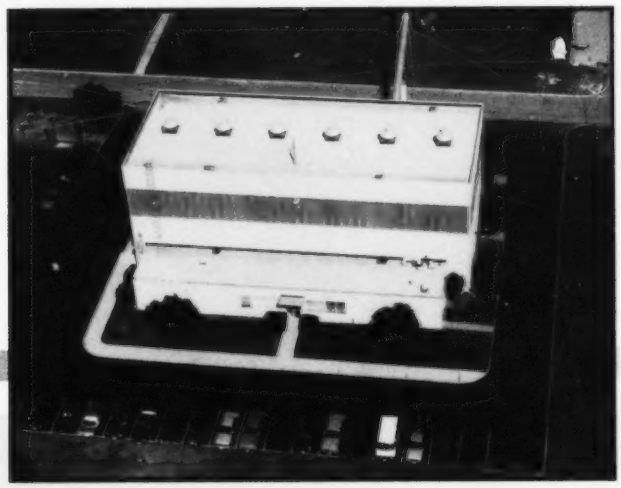
From the research conducted in the M&S Complex, advanced materials and fabrication techniques were developed. These techniques will, in turn, lead to advances in applied sciences such as aeronautics. Research done here has also led to the development and verification of life prediction theories that are useful in the design of advanced structural components.



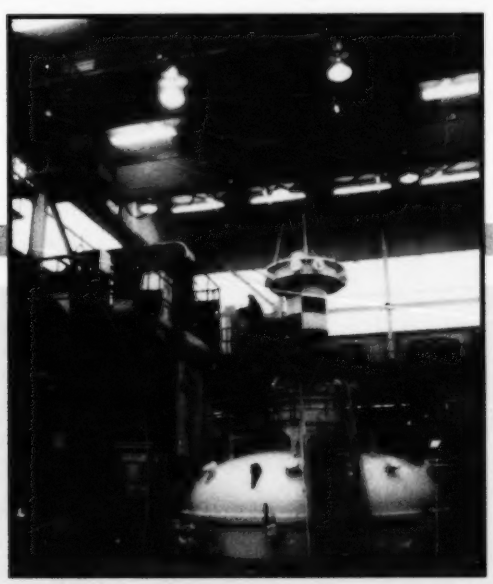


Top left: *Materials and Structures Complex.*
Lower left: *Axial-torsion test machine for elevated temperature fatigue testing.*
Below: *Materials characterization with scanning electron microscopy.*

Zero Gravity Research Facility



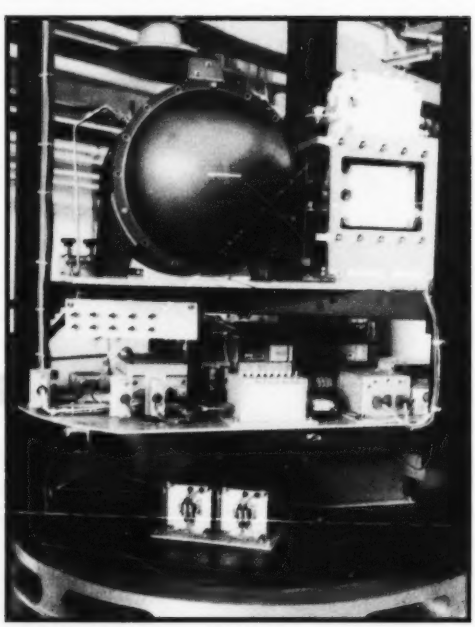
Above: *Zero Gravity Research Facility.*
Left: *Droplet formation experiment.*
Below: *Inserting an experiment package into Zero-G vacuum facility.*
Right: *Solid Surface Combustion Experiment.*



The Zero Gravity Research Facility (Zero-G) provides the opportunity to test experiments in a weightless state for up to 10 sec. The facility houses a 20-ft-diameter by 470-ft-long steel vacuum chamber encased in a concrete shell that extends 510 ft below grade. Test packages dropped from the top of the chamber experience less than one-millionth the normal pull of gravity during a nominal 5.18-sec fall through the low-drag vacuum environment. Projecting a package up from the bottom of the shaft and then allowing it to free-fall produces 10.4 sec of weightlessness.

The Zero-G Facility can accommodate test packages weighing between 500 and 2500 lb with payload envelopes of 3.6 ft diameter by 5 ft high, or 2 ft long by 1.3 ft wide by 1.5 ft high. A 315-ft^2 class-10 000 clean room is available for experiment assembly. The test capsule has 18 channels of telemetry and a high-speed motion picture system capable of 500 frames/sec. In addition, a computer-based data acquisition system is available onboard standard test packages. A light bar, consisting of 250 quartz-iodine lamps along the length of the shaft, allows placement of stationary cameras to monitor drops of unencapsulated test articles. Facility operational parameters are the following: ultimate vacuum of 10^{-2} torr (in 1 hr); microgravity duration of 5.18 sec; and a mean deceleration rate of 35 g, achieved with a 20-ft-deep deceleration cart filled with expanded polystyrene pellets.

Since 1966, when the facility became operational, more than 2500 experiment drops have been done here, investigating cryogenic propellant management, fluid transfer, combustion, heat transfer, and materials science. Programs supported during these years include Apollo, lunar device testing, Mars Lander, Skylab, Centaur, and at present, the shuttle and the space station microgravity experiments.



Space Experiments Laboratory

The Space Experiments Laboratory (SEL) has been designed to be a state-of-the-art facility devoted to space shuttle and space station experiments. The building provides laboratory and clean-room space to perform the construction, analysis, and testing required to develop experiment hardware. This building is attached directly to the existing Zero Gravity Research Facility.

The SEL contains a 6300-ft^2 class-100 000 high-bay clean room that can accommodate Spacelab pallet-size experiments and space station laboratory module ground-based activities. Near the high-bay area there are four additional class-100 000 clean rooms, totaling 2800 ft^2, for preparation of flight electronic boxes and mechanical subassemblies, and controlled storage of flight hardware. A computer/control room adjacent to the high-bay area is used to collect data from ground-based microgravity laboratory experiments. Eight separate laboratories totaling 4550 ft^2 are used to develop experiments in fluid physics, combustion, materials science, and heat transfer, and to develop specialized instrumentation such as lasers and electrical breadboards.

Since the first experiment on Mercury 7 in the 1960's, Lewis Research Center has been actively involved with in-space research. The Space Experiments Laboratory consolidates the Center's space experiments activities and augments other capabilities. The research and development conducted in this facility supports microgravity science and applications programs as well as in-space research and technology programs.

Left: *Space Experiments Laboratory (northeast perspective).*
Below: *Southeast view of SEL.*

Drop Tower

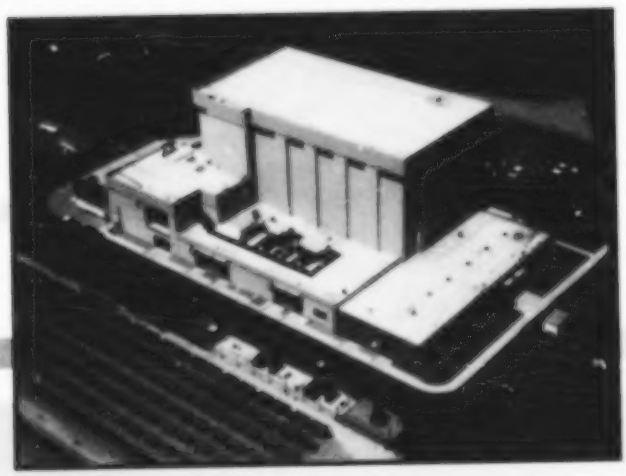
The Drop Tower allows researchers to conduct experiments in a microgravity environment for a period of 2.2 sec. The facility consists of an eight-floor (100-ft) tower connected to a shop and three laboratories. Experiments are enclosed in a drag shield that has a high weight-to-frontal-area ratio and a low drag coefficient. The drag shield also has three deceleration spikes attached to the bottom. The shield-experiment assembly is hoisted to the top of the tower and allowed to free-fall for about 89 ft. The package is stopped by the action of the deceleration spikes in a 7-ft-deep sand pit.

The facility can accommodate test articles weighing up to 350 lb and measuring up to 16 by 38 by 40 in. Laboratories and a shop equipped with such items as a fume hood, film motion analyzer, computers, machinery, and tools are available for experiment buildup, testing, and analysis. Data are acquired with a high-speed motion picture camera with framing rates of up to 1000 frames/sec, and an onboard data acquisition and control system that can record data from thermocouples, pressure transducers, flow meters, and other instruments. Operational parameters are 2.2 sec of reduced gravity at less than 10^{-5} g, and a mean deceleration of 60 to 70 g over a 0.75-sec period. Typically, 6 to 12 drops can be completed per day.

The Drop Tower supports basic and applied research in fluid dynamics, heat transfer, and combustion phenomena in low-gravity environments; it is also used for development and design verification of space experiment technology. The facility, which is operated at a relatively low cost, allows researchers to participate directly in experiment buildup and testing. It is ideally suited for thesis research and has been extensively used by graduate students as well as NASA research scientists.

Top left: *Drop Tower.*
Lower left: *Installing two-phase flow experiment package into drag shield.*

Power Systems Facility



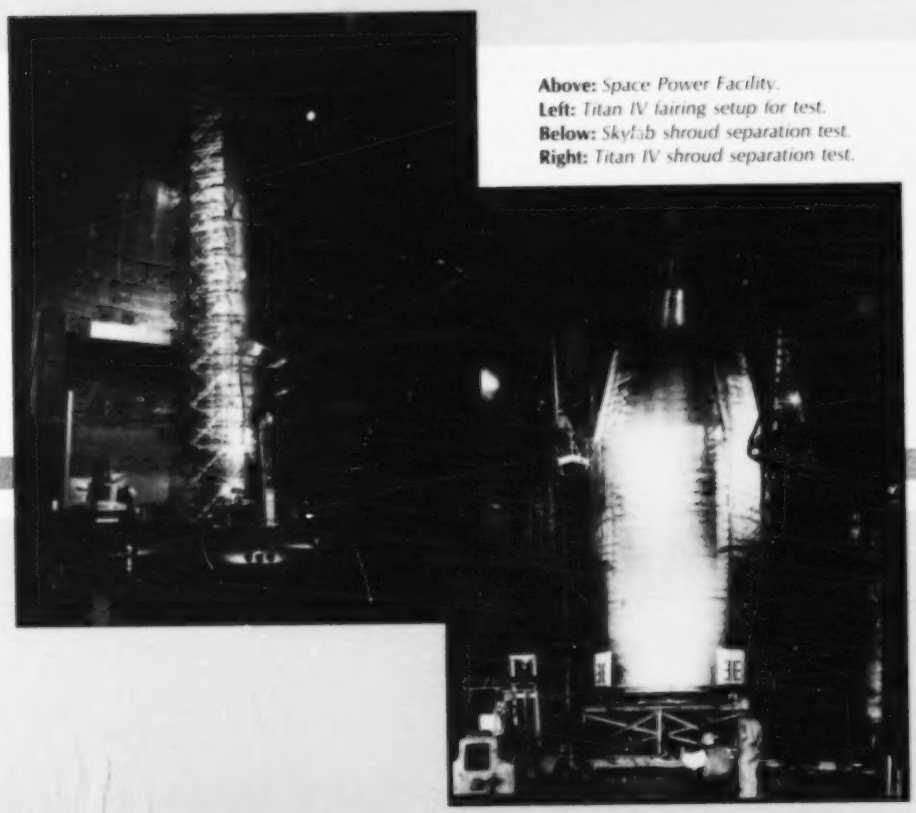
Above: *Power Systems Facility.*
Left: *Fault current testing of toll ring design proposed for space station.*
Below: *Power management and distribution test bed.*
Right: *Solar concentrator optical test facility.*

In the Power Systems Facility (PSF), which was completed in November 1988, electrical power systems for the Space Station Freedom are developed, tested, and validated. The PSF houses a number of specialized test beds that allow scientists and engineers to verify critical design concepts, to test prototype hardware and software, and to validate an entire system's performance through real-time simulations under actual loading and operating conditions. An adjacent solar array field, consisting of 960 solar cell modules, provides operational power to system hardware during testing and evaluation.

A major PSF feature is the main test area, which can be operated as a controlled-environment class-100 000 clean room. This area, which covers 8300 ft^2 with a clear height of 55 ft below a 10-ton crane, can accommodate optical testing of a full-scale (60-ft nominal diameter) solar concentrator. In addition, there are battery testing rooms with enhanced ventilation and blow-out panels for the added safety of personnel; a specialized test bed and support laboratory with a high-speed computer capable of running simulations in real time; power system controllers; graphic workstations; and a host minicomputer. Utilities available are service air, gaseous nitrogen, a 50-kW uninterruptible power supply, and 30 kW of solar array power at 160 V.

The PSF is the site of qualification testing of proposed battery designs, 5-yr life-cycle testing of the battery power storage system components, development of power management and distribution hardware, and development of system control software. In the future, validation testing of power system buildup will be conducted. (The space station power system will be incrementally expanded as the station is constructed; the PSF will simulate system performance at all stages of construction.) Subsequently, validation testing of the entire power system will take place under anticipated operating conditions. Ultimately, when the PSF houses a full-scale operating replica of the space station electrical system, it will provide ground support for the orbiting station, training for the crew, and long-range improvements to the system.

Space Power Facility



Above: *Space Power Facility.*
Left: *Titan IV fairing setup for test.*
Below: *Skylab shroud separation test.*
Right: *Titan IV shroud separation test.*

The Space Power Facility (SPF) houses the world's largest space-environment test chamber, measuring 100 ft in diameter by over 120 ft in height. The facility was designed and constructed to safely test both nuclear and non-nuclear space hardware in simulated low-Earth-orbit (LEO) environments.

This facility can sustain a high vacuum (10^{-6} torr); simulate solar radiation via a 57-ft-high quartz lamp array and a 400-kW arc lamp; and simulate LEO plasma via argon plasma generation. It also has a large experiment-assembly area (150 ft long by 75 ft wide by 76 ft high), a correspondingly large disassembly area where radioactive hardware can be safely disassembled; a 16 000-ft^2 office building; and a large instrumentation area equipped with computers and data acquisition equipment. A cryogenic cold wall is also available.

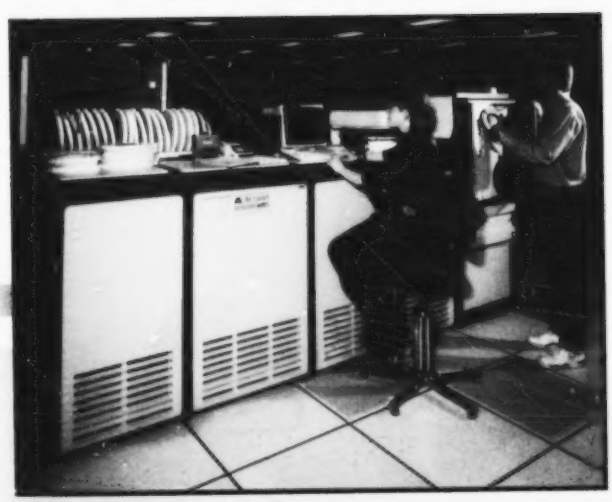
The Atlas I and Titan IV payload fairings and space-flight hardware for other programs were tested in this facility during 1990. In the future, the Ariane 5 payload fairing is scheduled to be tested for the European Space Agency, and electric power system tests are scheduled for the NASA Space Station Freedom project.

Research Analysis Center

Above: *Research Analysis Center.*
Left: *Sophisticated data recording and processing systems meet the high demands of Lewis research facilities.*
Below: *The Cray X-MP can process up to 200 million instructions per second.*
Right: *Parallel processors give researchers a test bed for improving analysis software.*

The Research Analysis Center (RAC) is the heart of all NASA Lewis computing and telecommunications, housing mainframe computers, communications equipment, closed-circuit television equipment, and facilities for transferring data to and teleconferencing with other NASA centers and private industry. The building includes a 31 000-ft^2 central computer room and offices for personnel of the Computer Services Division. These personnel are responsible for providing a wide range of computer capabilities and services including purchasing, installing, and operating large-scale computer systems; computer training; installing and repairing workstations; operating mainframe and communications equipment; and providing technical programming support for Center researchers.

The RAC provides central network control for thousands of individual workstations located throughout the Center; high-speed data acquisition for sophisticated research test applications; six closed-circuit video channels; video conferencing with and data transfer to other NASA centers and off-site locations; and support for a multitude of complex engineering and scientific computer program applications. The facility houses several supercomputers, each capable of millions of instructions per second; two powerful mainframes; numerous minicomputers; a large variety of special-purpose computers and data acquisition equipment; a video control room; central telephone equipment; and satellite communications equipment.



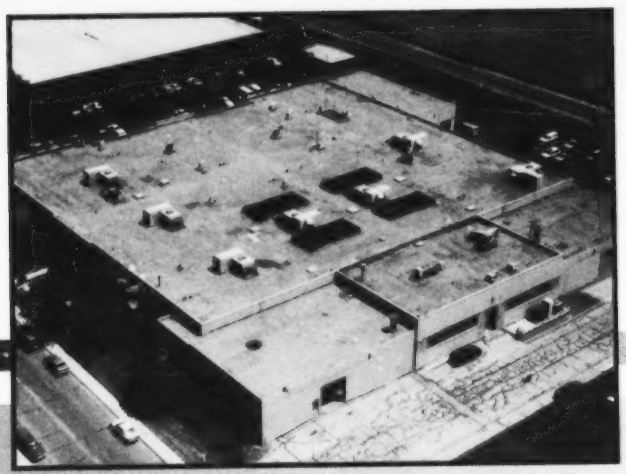
Technical Support

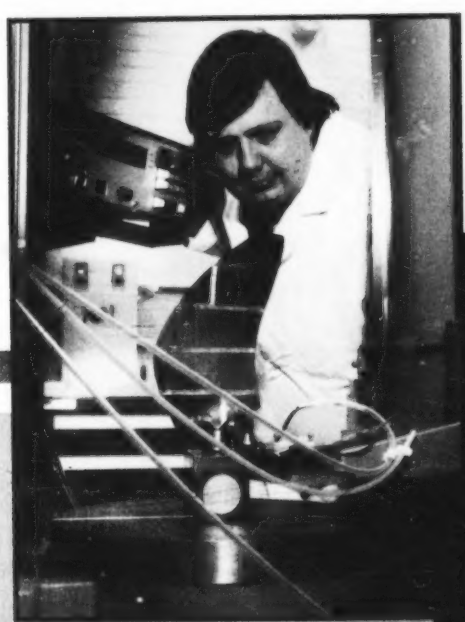
Central Process Air System

Above: *Central Control Building.*
Left: *Electrical dispatch consoles monitor and control electrical distribution system.*
Below: *Operating the electrical dispatch console.*
Right: *Central control room operators control and monitor Lewis central air and electrical distribution systems.*

The Central Process Air System supplies test cells with compressed air and vacuum at various pressures, temperatures, humidity, and flow rates, simulating altitude flight conditions. The processed air is provided by diverse compressors and exhausters (powered by large drive motors), along with turboexpanders, heaters, dehydrators, and other auxiliary equipment, much of which is located in the Central Air Equipment and Engine Research Buildings. Air supplies are routed to over 100 test cells through a complex piping distribution network; dispatchers precisely monitor and control the system through a computer in the Central Control Building. This facility handles over 7000 channels of information and, altogether, controls critical elements of the service air, altitude exhaust, combustion air, and electrical distribution systems.

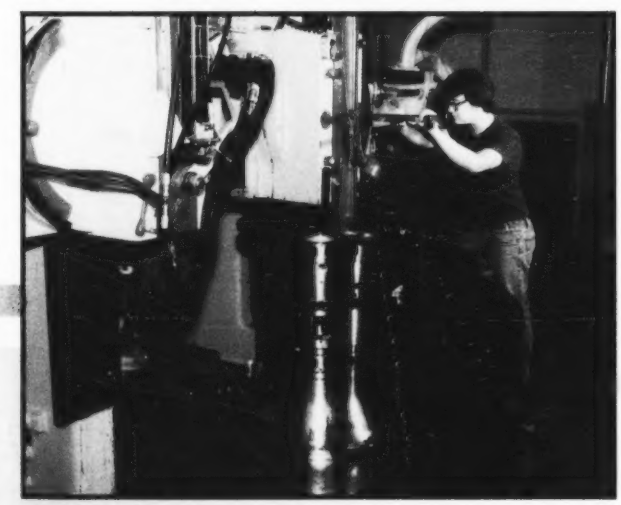
Technical Services Building





Above: *Technical Services Building.*
Left: *Precision inspection and profile plotting of advanced graphite composite turboprop blade.*
Below: *Connecting instrumentation wiring from strain gages on a centrifugal compressor.*
Right: *Machining a compressor case for the supersonic flow-through compressor.*

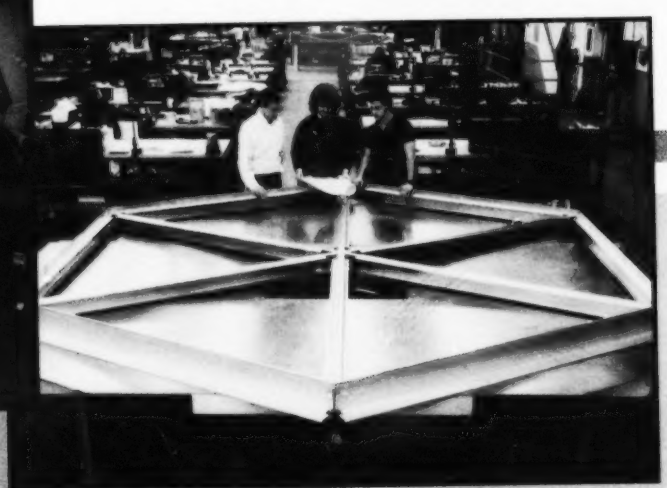
Work done in the Technical Services Building supports research that requires unique fabrication and test services. Here, there are over 20 000 ft^2 of general and specialized machine shops in addition to other dedicated assembly, special process, and test areas for performing a wide variety of specialized services. Examples of these services are metal machining processes such as wire electric discharge machining and large-scale boring; ultra-precision machining such as microdrilling and fine diamond cutting; nondestructive testing by x-ray, ultrasonic, and dye penetrant methods; special processes such as controlled-environment heat treatments, plasma spray coatings, and electron-beam welding; metallurgical tasks, including materials identification and strength testing; and instrumentation services, including development, installation, and repair of sensors and instrumentation systems.



Technical Support

Fabrication Shop

Above: *Fabrication Shop.*
Left: *Assembling a test rig for a shuttle spacelab microgravity experiment.*
Below: *Fabricating prototype hardware for space station power systems.*
Right: *Fabricating advanced carbon/graphite composite turboprop blades.*



Research activities that require the manufacture of unique jigs, components, structures, and one-of-a-kind experimental apparatus rely on the Fabrication Shop. The facility encompasses about 40 000 ft^2 of metal-working shops in addition to separate shops dedicated to precise construction of wood, plastic, and other nonmetallic objects. The fabrication shop has press brakes, forming rollers, punches, a computer-aided-design system, welding equipment, spray booths, lathes, and other light machinery available. A 30-ft-high bay with overhead cranes accommodates construction or repair of very large items. The range of services provided through this facility varies widely, from fabricating precise small-scale prototypes, models, and parts, to constructing large-scale structural test hardware weighing several tons.

Technical Support

Flight Research Building

Above: *Flight Research Building.*
Top left: *T-34 research support aircraft.*
Lower left: *Learjet.*
Below: *DH-6 icing research aircraft.*
Right: *OV-10A research aircraft.*

The Flight Research Building is a hanger used to store and service the Center's research and administrative aircraft. It also provides office and work space for flight operations personnel.

T-34 Research Support Aircraft

The T-34B is a nonpressurized fully acrobatic aircraft with a speed range of 50 to 280 kn. Originally acquired for programs designed to enhance scientific education in secondary schools, the aircraft is readily adaptable as a low cost option for conducting a variety of experiments. A self-contained video/audio system, installed as part of the basic aircraft, allows study of rear-seat occupants/experiments, and two 70-mm Hassilblad infrared and standard imaging cameras mounted in the fuselage permit near-nadir views of objects below the aircraft.

Learjet

The Learjet Model 25 is an 8- to 10-passenger high performance aircraft that has been modified to accommodate a variety of research experiments. It has a range of over 1000 nmi at a normal cruise speed of 420 kn and is certified to 45 000 ft. The Learjet is fully instrumented to fly low-gravity trajectories and also has a nadir-looking optical-glass viewport. This aircraft serves as an economical test bed for suitable low-gravity experiments and for a wide variety of remote sensing and photographic applications.

DH-6 Icing Research Aircraft

The DH-6 Twin Otter research aircraft is a versatile test bed that has been modified to conduct inflight icing research. It is equipped with a full complement of sophisticated instruments that measure and record important properties of icing clouds, and high-speed stereographic camera systems that document ice accretion characteristics. The aircraft supports the Lewis Icing Research Tunnel and inflight tests of new icing-protection systems; it is currently being used to acquire extensive experimental data about icing effects on aircraft flight characteristics.

OV-10A Research Aircraft

The NASA Lewis OV-10A research aircraft is a twin turboprop that can reach speeds between 50 and 325 kn. It was acquired to do inflight propeller acoustics testing for the Propfan Test Assessment Program. Its unique ability to achieve different relative propeller rotational directions by substituting different engine/propeller acoustical characteristics is necessary to validate advanced design concepts.

Technical Support

Research Support Building

Construction of the Research Support Building (RSB) is the most important objective required by the Lewis Strategic Housing Plan. This facility will provide the necessary office and engineering areas for expanding research programs. The RSB, which will be located in the west area of the Center, will feature three stories in addition to a basement level. The 154 000-ft^2 building will accommodate approximately 560 people. It will provide space for the following: CAD/CAE or automated drafting/design; LIMS (Lewis Information Management System) equipment; employee cafeteria; conference rooms; offices; video/teleconferencing rooms; security work rooms; a blueprint/drawing/reproduction/record files area; and other service-related areas.

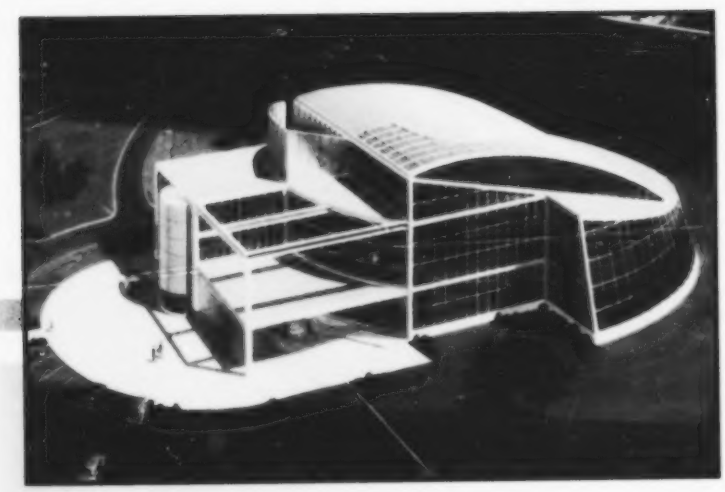
Research Support Building

Ohio Aerospace Institute

A 50 000-ft^2 headquarters for the Ohio Aerospace Institute (OAI) is scheduled for completion in 1992. NASA is providing land for the facility, and the state of Ohio is funding construction at an estimated cost of $10.2 million. The facility will be the operational base for a unique public-private consortium representing nine Ohio universities, NASA Lewis, Wright Research and Development Center, and private industry.

The OAI will provide classroom and laboratory areas, office space, meeting areas, and a state-of-the-art telecommunications center capable of sending and receiving educational programming to and from locations throughout Ohio.

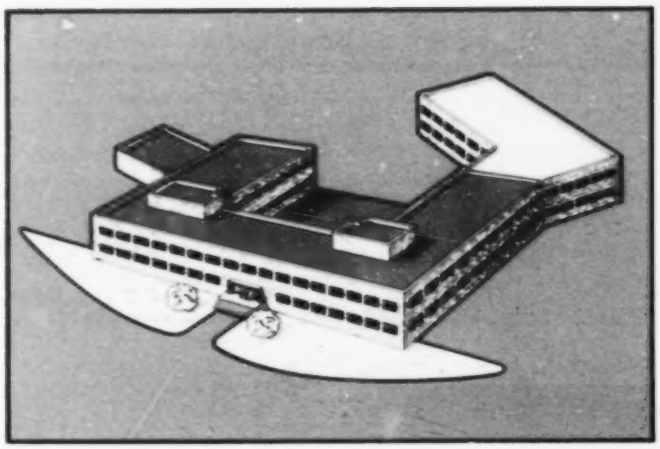
The goal of the OAI is to advance Ohio's graduate and continuing education programs in aerospace and related technologies, and to facilitate collaborative research. To achieve these goals, OAI will sponsor programs that assist Ohio universities in graduating more students in aerospace technologies, and programs that build an organization where professionals from academia, private industry, and government can collaborate on research projects for mutual advantage. Such accomplishments will enhance Ohio's ability to attract more aerospace-based industry and will accelerate the transfer of technology from the university and federal laboratories to private industry, where development and commercialization of new products and services can take place.



Ohio Aerospace Institute

Composite Technology Center

The Composite Technology Center (CTC) will be a new and unique facility that will provide NASA with the opportunity to lead in the technical development of a new generation of high-temperature materials. It will also enable Lewis to continue its leadership role in tailoring composite systems for aerospace applications. The CTC will evolve from a combination of new construction and the revitalization of an existing building. Its features will enable an interdisciplinary interface science laboratory to support NASA composite development, enable high-resolution microstructural and microchemical analysis through electron and/or optical characterization, and allow fabrication of prototype composite test components for application-related mechanical testing.



Composite Technology Center.

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